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TESTS OF A 1/40-SCALE WING-HULL MODEL AND A 1/10-SCALE FLOAT-STRUT MODEL OF THE HUGHES-KAISER CARGO AIRPLANE IN THE TWO-DIMENSIONAL LOW-TURBULENCE PRESSURE TUNNEL

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NACA

WASHINGTON

MEMORANDUM REPORT

for the

Department of Commerce

TESTS OF A 1/40-SCALE WING-HULL MODEL AND A 1/10-SCALE FLOAT-STRUT MODEL OF THE HUGHES-KAISER CARGO AIRPLANE IN THE TWO-DIMENSIONAL LOW-TURBULENCE PRESSURE TUNNEL

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INTRODUCTION

At the request of the Department of Commerce, aerodynamic and hydrodynamic tests have been made of a 1/40-scale wing-hull model and a 1/10-scale float-strut model of the proposed arrangement of the Hughes-Kaiser cargo airplane. The aerodynamic tests were made in the NACA two-dimensional low-turbulence pressure tunnel and the results are presented in this report. The hydrodynamic tests were made in the NACA tank and are being reported separately.

The aerodynamic tests were made primarily to study the drag characteristics of these models as originally designed and to determine, if possible, how the proposed designs could be improved. The investigation accordingly included tests of these models as received and after various modifications had been made. Some of these modifications were made as the result of hydrodynamic tests at the NACA tank. Whenever practicable, additional tests were made to study the lift characteristics of these models. The tests of the wing-hull model were made at a Reynolds number of approximately 22.5 million based on the model-hull length of 62.25 inches. The float-strut model was tested at a Reynolds number of approximately 7 million based on the model-float length of 28.00 inches.

MODELS

Wing-hull model.- The model arrangement tested is shown in figure 1 in the original condition and in figure 2 with the added chine-flare strips as recommended by the

NACA tank. The span of the model was 36 inches (tunnel test-section width); therefore, only the inboard portion of the wing (approximately 37.5 percent of the full span) was modeled. The airplane wing tapers from an NACA 63(420)-321 root section to an NACA 65,3-418 section at the tip. The airplane hull was developed from and is similar to the NACA model 84-F hull. The wing and hull were constructed of mahogany and all surfaces were painted and sanded until aerodynamically smooth. For some tests fillets made of modeling clay were added to the model at the wing-hull junction. These fillets were of the expanding-radius type and were very small forward of the maximum thickness of the wing. At the wing trailing edge the fillet radii were 1 inch and 0.563 inch, respectively, on the upper and lower wing surfaces. The fillets extended along the hull aft of the intersection for a distance of 2.25 inches. The step fairings used for some of the tests were made of modeling clay and extended approximately 8.5 inches aft of the step. Roughness was applied to the hull by two methods, first, by gluing number 50 thread around the hull 3.1 inches aft of the bow and later by shellacking 0.012-inch carborundum grains to the hull for a distance of 3.1 inches aft of the bow.

Float-strut model.- The model arrangement tested is shown in figure 3. The model was constructed of mahogany; all the surfaces were painted and sanded until aerodynamically smooth. For these tests the model was attached to a 36-inch-chord airfoil in such a manner that the strut leading edge, extended, intersected the quarter-chord point of the wing for all angles of incidence of the float. The 36-inch chord of the model approximates, to the same scale, the chord of the airplane wing at the juncture of the wing and float strut. The airfoil used was chosen only because of its availability and was an NACA 66,2-216 section. Figure 4(a) shows the float-strut model and the 36-inch-chord airfoil mounted in the test section. The wing was mounted approximately 18 inches above the center line of the tunnel so that the float and lower portion of the strut would be within the working limits of the wake-survey mechanism. As a result of tests in the NACA tank, a spray strip was added, the step was removed, and a cove was cut into the after section of the chine (fig. 4(b)).

SYMBOLS

The coefficients and symbols used in this report are defined as follows:

C_{L_M} model lift coefficient $\frac{L_M}{qS_M}$

ΔC_D airplane-drag-coefficient increments $\frac{\Delta D}{qS}$

C_{D_A} drag coefficients based on the maximum cross-sectional area of the hull $\frac{D_c - D_w}{qA}$

L_M total lift on the model

S_M wing area of the model

q dynamic pressure of air $(\frac{1}{2}\rho V^2)$

ΔD drag of surveyed portion of the model scaled to full size

S total wing area of the airplane

D_c drag of surveyed portion of wing-hull combination

D_w drag of surveyed portion of the wing alone

A maximum cross-sectional area of the hull

α angle of attack of the model wing

α_f pitch angle (angle of attack of the hull)

TEST METHODS

The lift coefficients were obtained by measuring the reaction of the lift on the floor and ceiling of the tunnel (reference 1). The lift data are presented as model lift coefficients C_{L_M}.

The drag measurements were made by the wake-survey method (reference 1). The drag data are presented as airplane-drag-coefficient increments ΔC_D because the differences in drag coefficient resulting from modifications of the arrangements represent directly the resulting change in drag coefficient of the actual airplane. The value of this drag coefficient also represents the contribution to the total airplane drag coefficient of the portion of the model surveyed.

Spanwise drag surveys were made over the central 20 inches of the model span. By intergrating these survey diagrams the airplane-drag-coefficient increments for the wing-hull model were determined. The model wing area surveyed corresponds to 28.2 percent of the actual airplane wing area. A typical survey for one condition is presented in figure 5. The section drag coefficients shown in this figure are based on the mean geometric model chord of 13.72 inches.

The airplane-drag-coefficient increments for the float-strut model were obtained by the integration of drag surveys made over the float and lower 12 inches of the strut.

To compare the drag coefficients for this model with those of other hulls, the coefficients were also based on the maximum cross-sectional area and are presented as drag coefficients C_{D_A}.

RESULTS AND DISCUSSION

<u>Wing-hull model</u>.- The important lift data obtained are presented in figure 6. Since minor modifications to the hull had little effect on the lift characteristics, these data are not presented. The incidence of the hull is shown to have an appreciable effect upon the angle of zero lift, the slope, and the maximum lift coefficient. These changes would have been much less if the total wing area of the airplane had been represented on the model.

The drag data for each model arrangement were obtained at lift coefficients corresponding approximately to the expected high speed, cruising, and climb conditions for the airplane. The drag data obtained are presented in figures 7(a) and 7(b). A comparison between these figures shows that the step fairing used with wing incidences of 2° and 4° appreciably lowered the drag coefficients of the model. The addition of wing fillets reduced the drag coefficients obtained with a wing incidence of 2° but gave a small increase in drag with the wing incidence increased to 4°. The increased chine flare added to the model following hydrodynamic tests caused a small increase in the drag coefficients. Doors, mooring apparatus, and other protuberances would be expected to prevent extensive laminar flow over the actual airplane hull; therefore, roughness was added to the model to determine the drag coefficients of the hull with fixed transition. At a lift coefficient of 0.25, cementing 0.012-inch carborundum particles to the hull increased the drag-coefficient increment 9 percent at 4° incidence and gluing number 50 thread just aft of the bow increased the drag-coefficient increment 5 percent at 7° incidence.

The differences between the values for the wing-hull combination and those for the wing alone represent the drag and interference of the hull expressed directly as airplane-drag-coefficient increments. These data are chiefly remarkable for the unusually low drag increments caused by the hull. This is clearly indicated in figure 8 where a comparison of the drag coefficients (based on the maximum cross-sectional area) shows that the Hughes-Kaiser hull, a modified NACA model 84-F, with fixed transition gave considerably lower drag coefficients than were obtained with the NACA model 84-F (reference 2) with fixed transition. The more favorable results indicated by the present tests may be partially attributed to possible favorable interference between the wing and the hull. The Hughes-Kaiser hull with fixed transition gives lower drag coefficients than other comparable NACA hulls (references 3 and 4) in a smooth condition and the coefficients obtained with the hull in a smooth condition are much lower.

Float-strut model.- The accuracy of the lift data obtained during the tests of this model was doubtful: therefore, no lift coefficients are presented.

The drag data are presented in figure 9 for the three float settings tested. The afterbody step is shown to cause an increase in drag for all three float positions. Changes in incidence of the float and strut to the wing did not affect the drag coefficients to any appreciable extent. The addition of the spray strip and cove increased the drag of the model.

Tuft observations were made with and without the step in the afterbody and with the float keel line paralled to the chord line of the wing. The results of these tuft studies are presented in figures 10 and 11. With the step in the afterbody of the float, the air flow generally was steady except over the surface just aft of the step. The flow over the bottom of the float just aft of the step was separated. At a point midway along the bottom aft of the step the flow was intermittently separated, indicating that the air stream was closing back into the surface. With no step in the afterbody, the flow over the float was steady except near the rear of the chine line. The air separated locally as it flowed over the chine line, but returned to a steady condition over the remainder of the float.

CONCLUDING REMARKS

Wing-hull model.- The results show that, for the model tested, the incidence of the hull had an appreciable effect upon the angle of zero lift, the slope, and the maximum lift characteristics. Minor modifications to the hull had little effect on the lift characteristics of this model.

The model as originally tested showed unusually low drag coefficients for all angles of incidence, and the addition of a step fairing lowered these drag coefficients 7.5 percent. The addition of wing fillets caused only small changes in drag. The added chine flare caused small increase in the drag coefficients of this model in the high-speed condition. A moderate increase in the drag coefficients was obtained with transition fixed just aft of the bow.

Float-strut model.- The results show that changes in incidence did not appreciably affect the drag coefficients of the model. An increase in drag-coefficient increment of over 30 percent was obtained with a step in the afterbody of the float. The addition of the spray strips and the cove also caused an appreciable increase in drag.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 24, 1943.

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2. Parkinson, John B., Olson, Roland E., Draley, Eugene C., and Luoma, Arvo A.: Aerodynamic and Hydrodynamic Tests of a Family of Models of Flying-Boat Hulls Derived from a Streamline Body - NACA Model 84 Series. NACA A.R.R. No. 3I15, Sept. 1943.

3. Hartman, Edwin P.: The Aerodynamic Drag of Flying-Boat Hull Models as Measured in the N.A.C.A. 20-Foot Wind Tunnel - I. T.N. No. 525, NACA, 1935.

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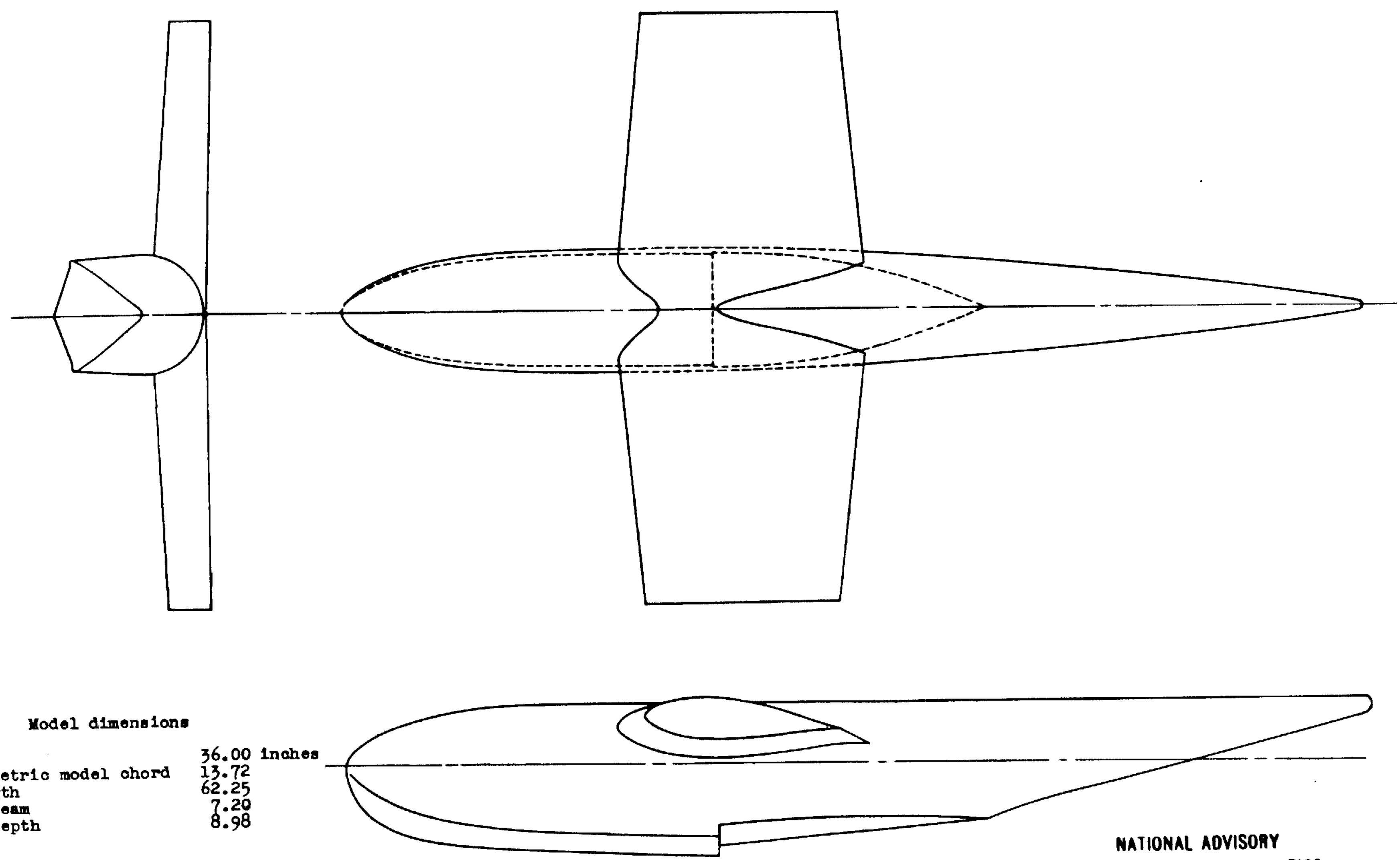

Model dimensions

Model span	36.00 inches
Mean geometric model chord	13.72
Hull length	62.25
Maximum beam	7.20
Maximum depth	8.98

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Figure 1 .- Drawing showing the arrangement of the 1/40-scale wing-hull model of the Hughes-Kaiser Cargo Airplane.

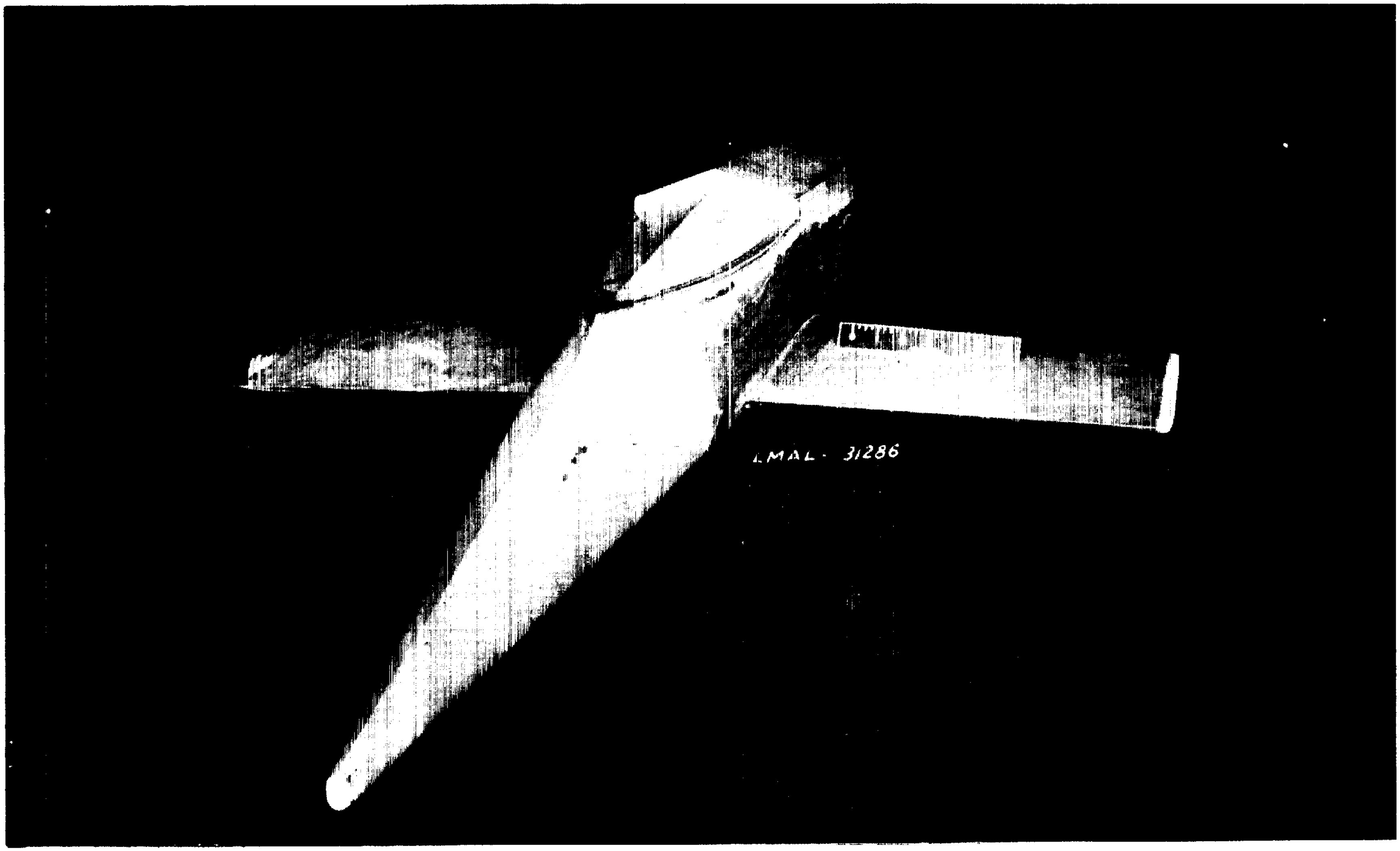
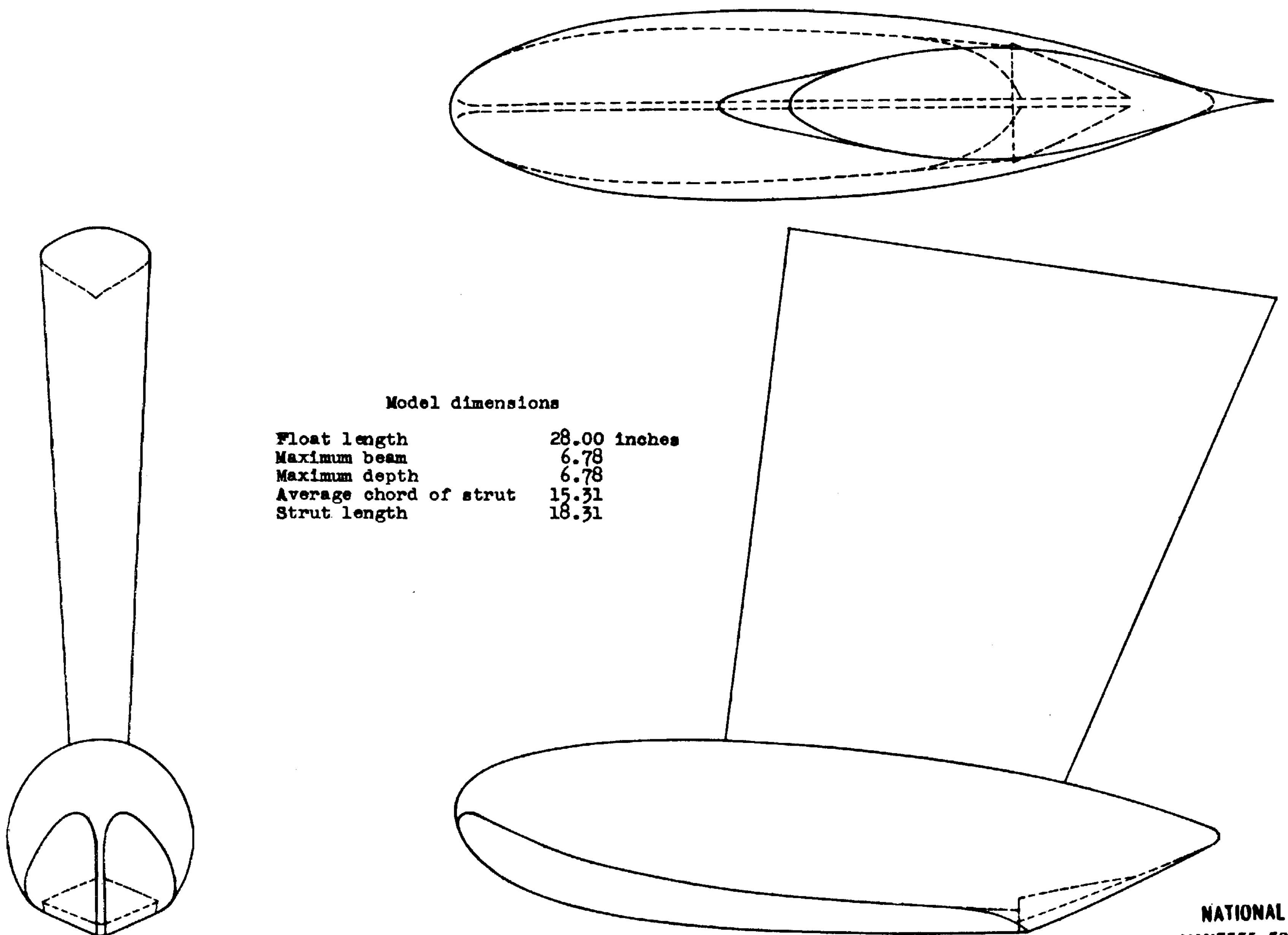


Figure 2.- Photograph showing the added chine flare on the $\frac{1}{40}$-scale wing-hull model of the Hughes-Kaiser cargo airplane.



Model dimensions

Float length	28.00	inches
Maximum beam	6.78	
Maximum depth	6.78	
Average chord of strut	15.31	
Strut length	18.31	

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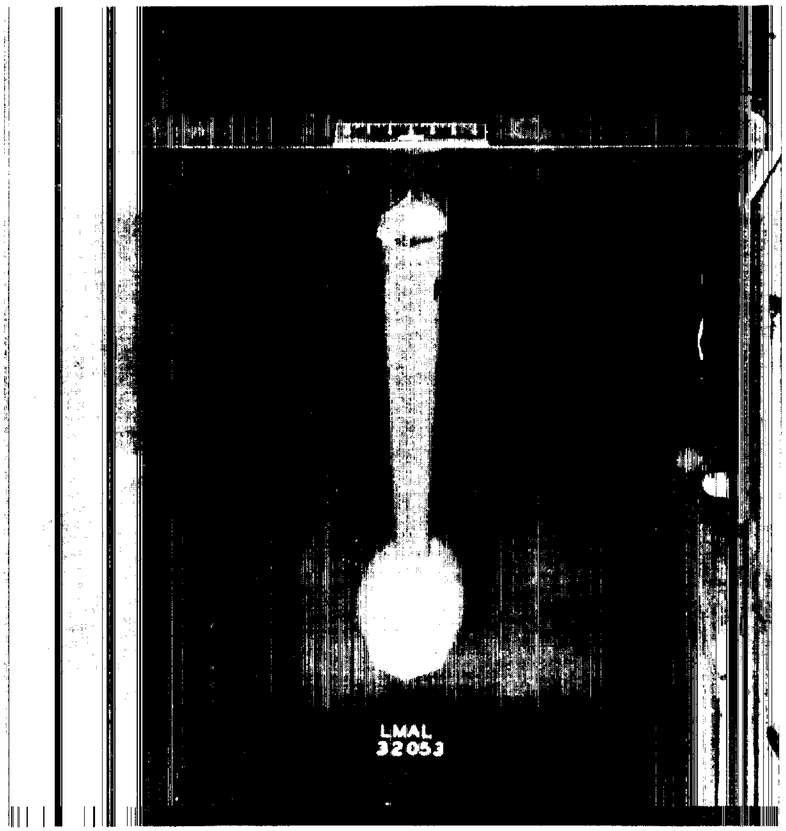
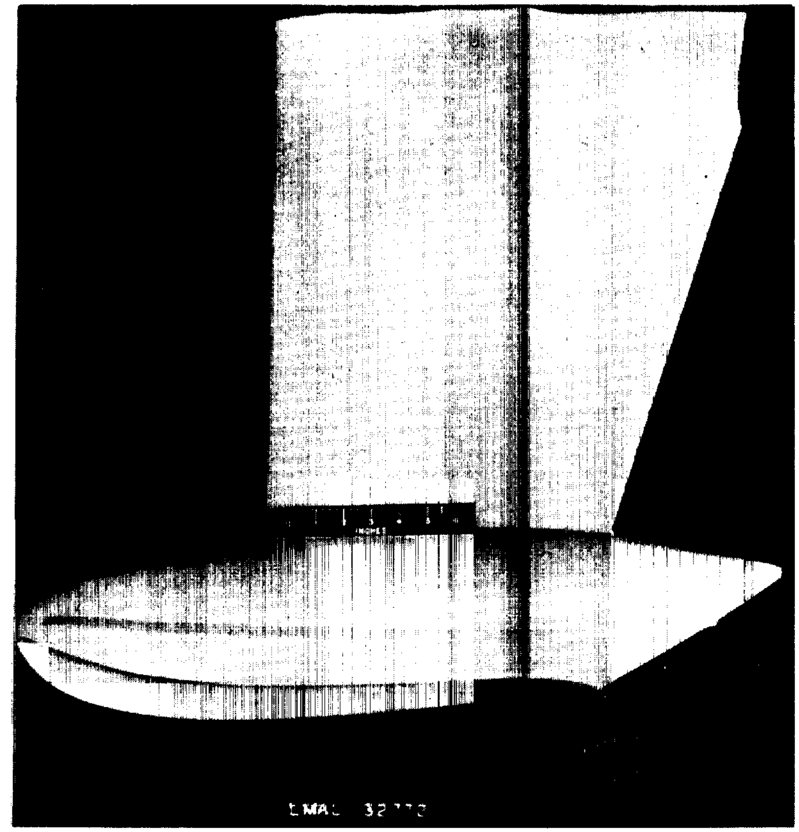
Figure 3.- Drawing showing the arrangement of the 1/10-scale float-strut model of the Hughes-Kaiser Cargo Airplane.



(a) Float-strut model attached to 36-inch-chord airfoil and installed in the tunnel.



(b) View showing float-strut with spray strip and cove.

Figure 4.- Photographs of the $\frac{1}{10}$-scale float-strut model showing method of installation and float modification.

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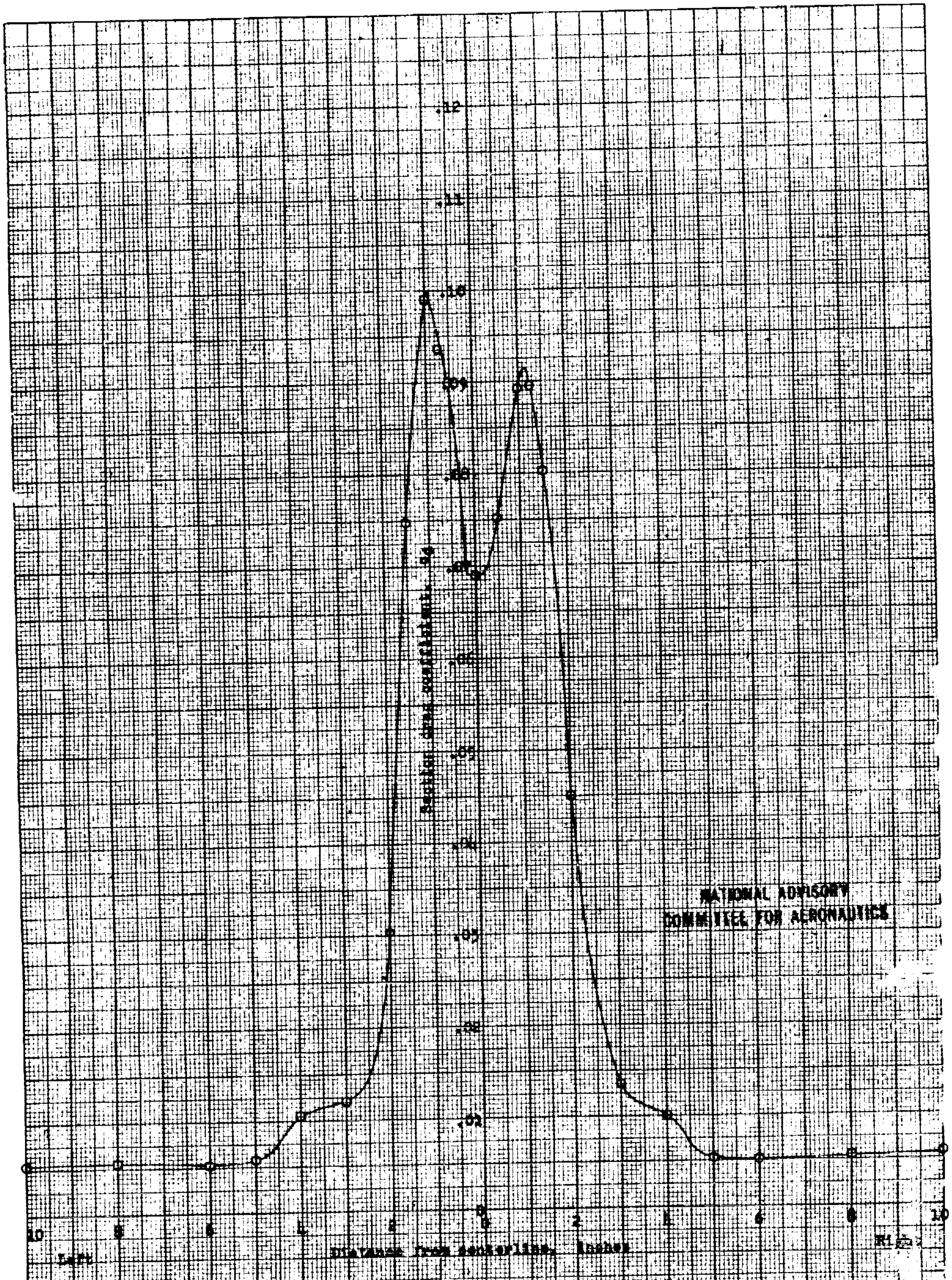

Figure 5.- Spanwise variation of section drag coefficients for the 1/40-scale wing-hull model of the Hughes-Kaiser Cargo Airplane; no wing fillets, step fairings, or roughness; incidence, 7°; model lift coefficient C_{L_M} = 0.182; R, 22.5 × 10^6. Test, TDT 325.

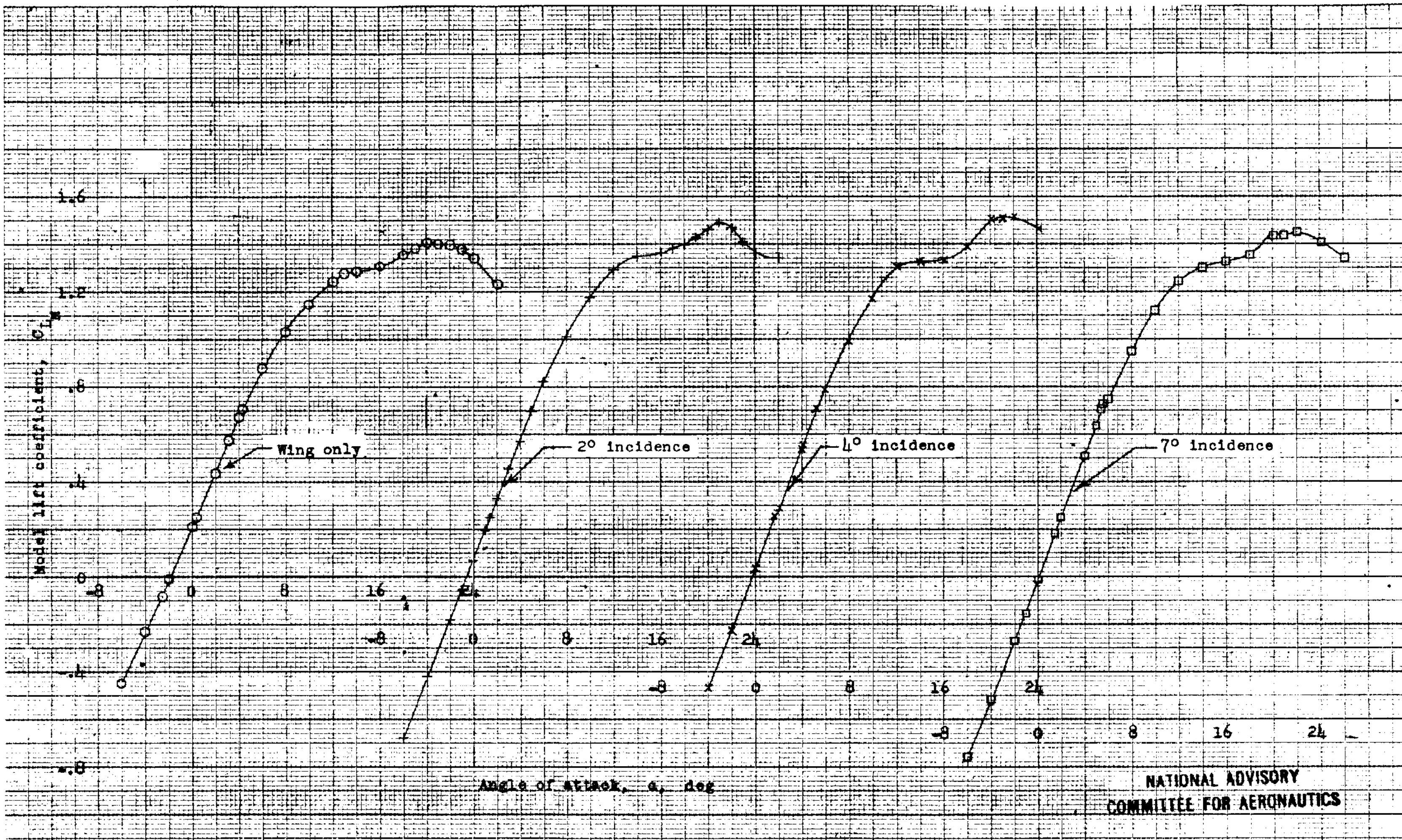

Figure 6.- Lift characteristics of the 1/40-scale wing-hull model of the Hughes-Kaiser Cargo Airplane; no wing fillets, step fairing or roughness; R, 22.5×10^6. Tests, TDT 325, 327, 332.

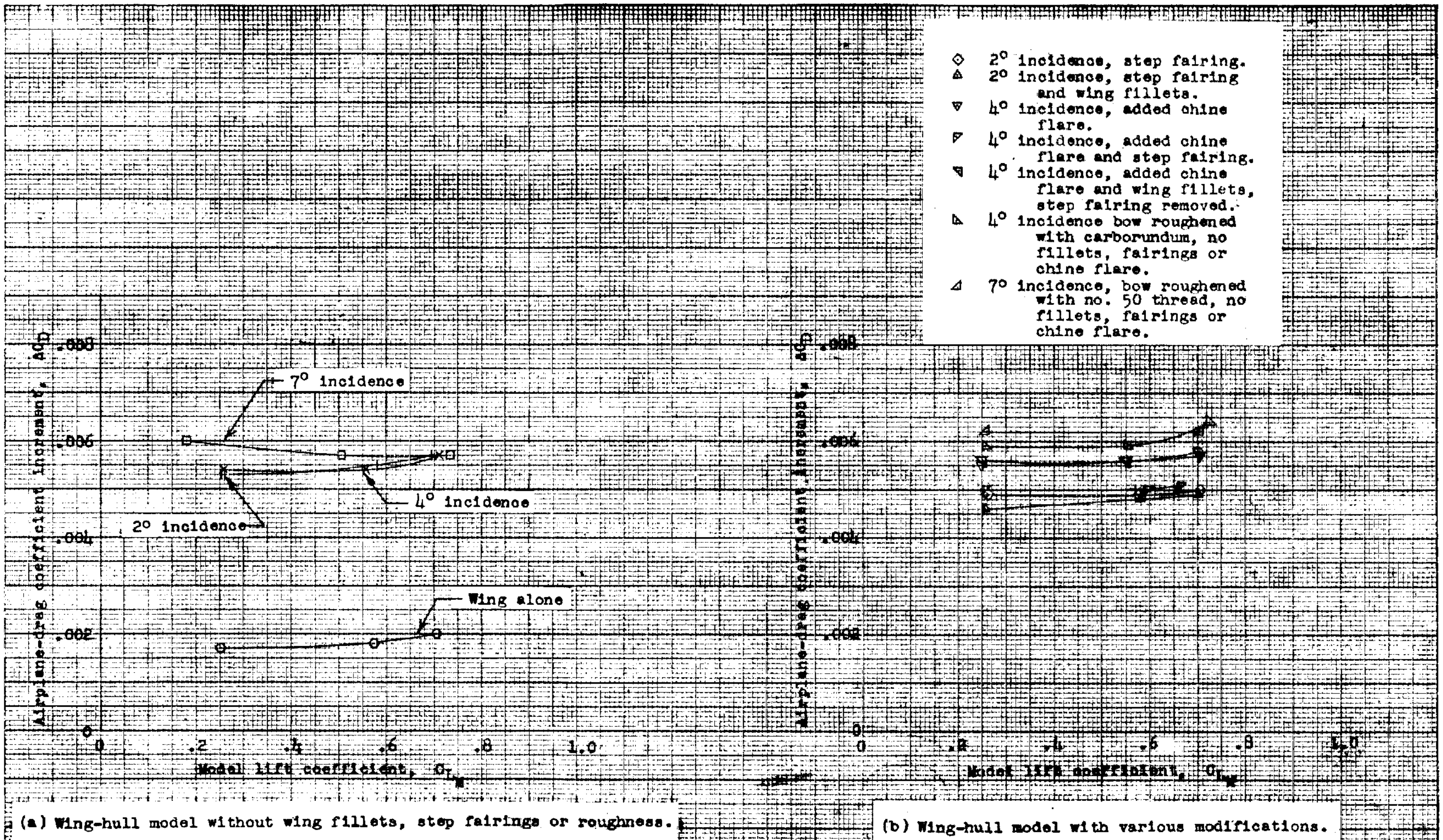

Figure 7.- Drag characteristics of the 1/40-scale wing-hull model of the Hughes-Kaiser Cargo Airplane; R, 22.5×10^6. Tests, TDT 325, 327, 332.

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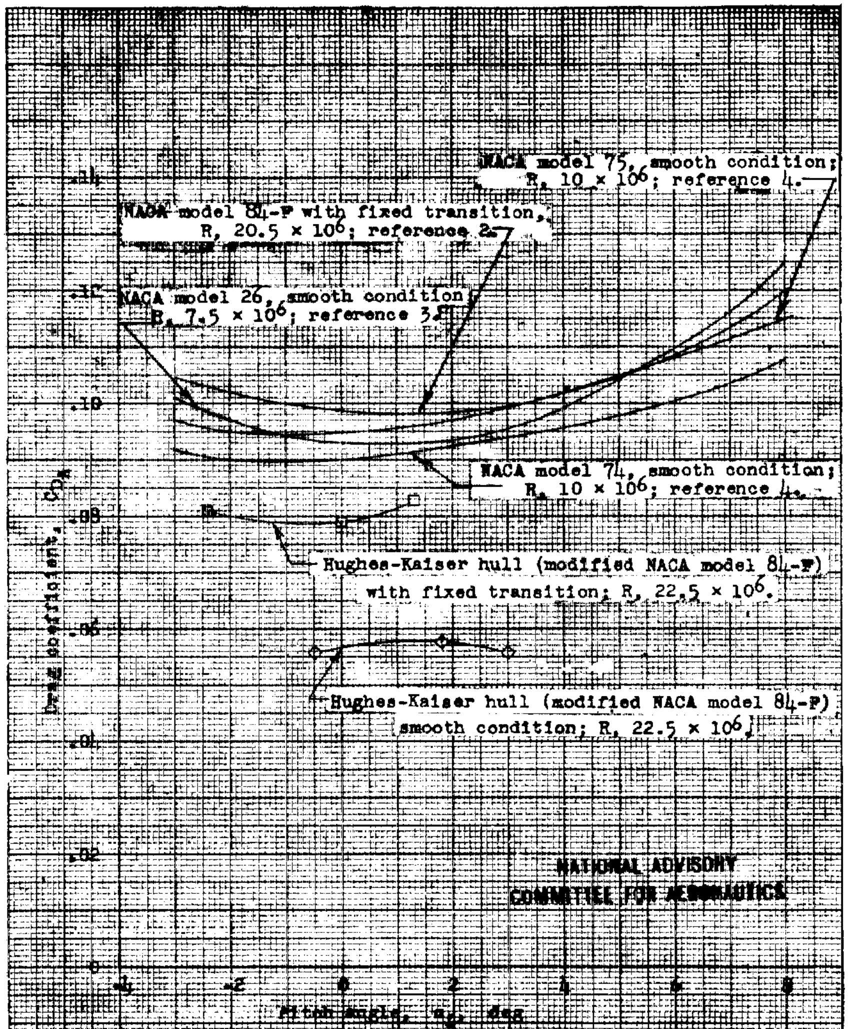

Figure 8 .- Drag characteristics of the Hughes-Kaiser flying boat hull as compared with other hull forms.

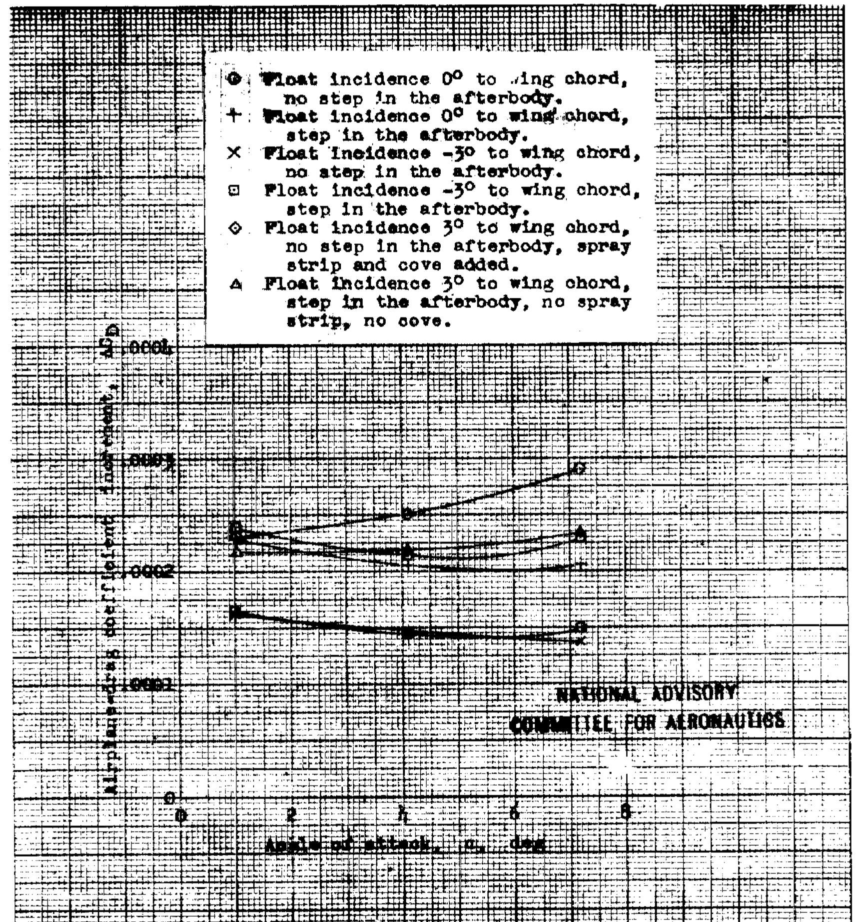

Figure 9 .- Drag characteristics of the 1/10-scale float-strut model for the Hughes-Kaiser Cargo Airplane; R, 7.0 × 10^6. Tests, TDT 386, 389.

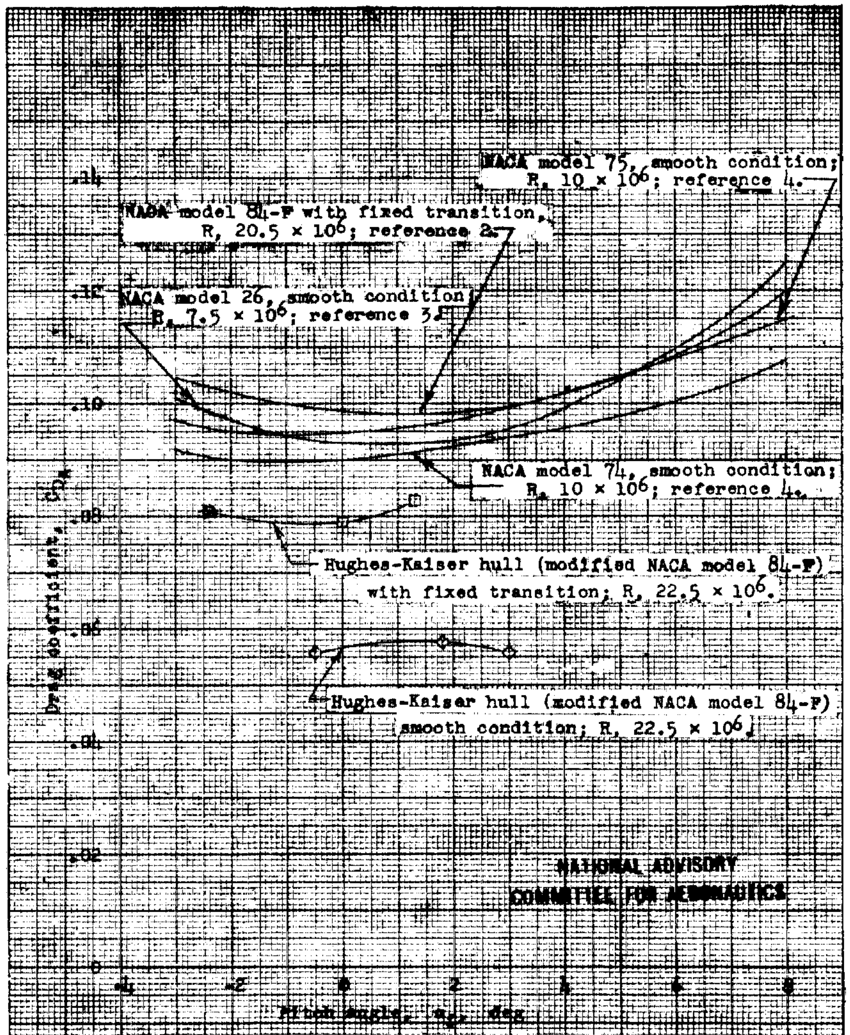

Figure 8 .- Drag characteristics of the Hughes-Kaiser flying boat hull as compared with other hull forms.

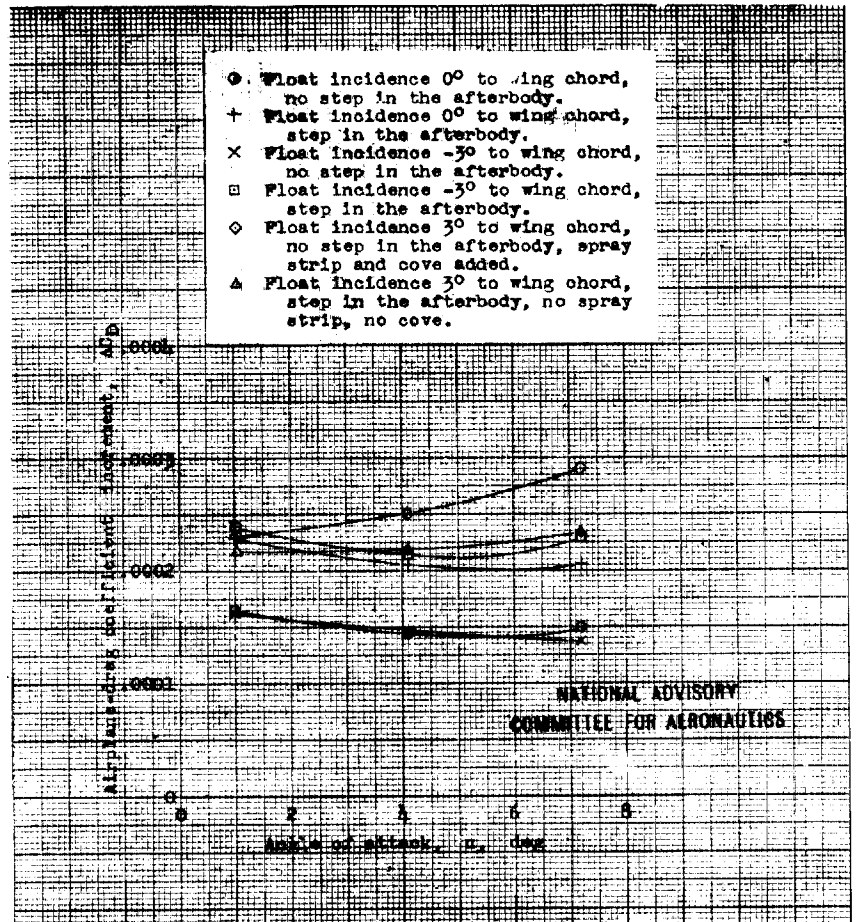

Figure 9 .- Drag characteristics of the 1/10-scale float-strut model for the Hughes-Kaiser Cargo Airplane; R, 7.0 × 10^6. Tests, TDT 386, 389.

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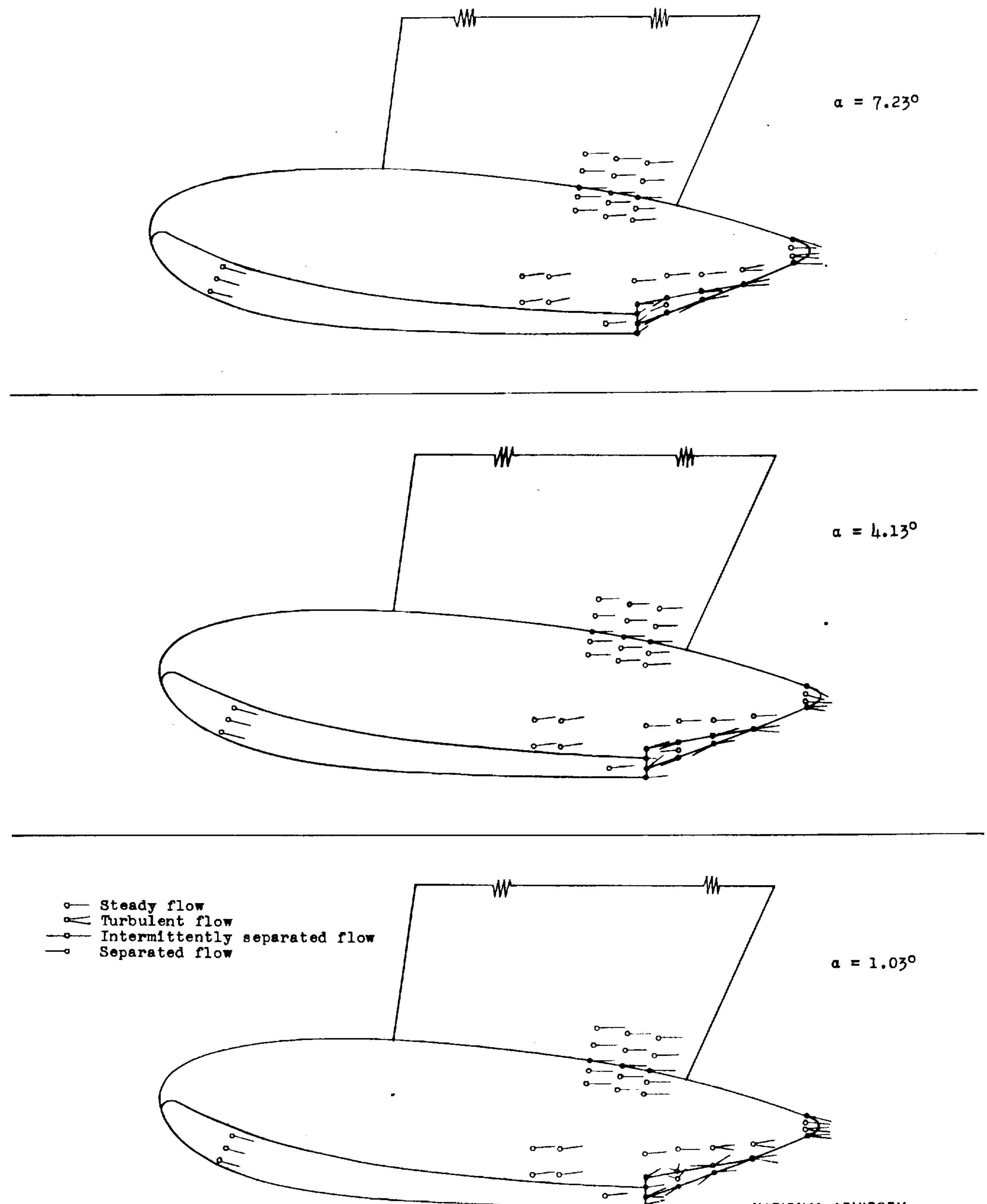

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Figure 10.- Tuft observations of the 1/10-scale float-strut model for the Hughes-Kaiser Cargo Airplane; step in float afterbody; float incidence 0° to wing chord; R, 7.0×10^6. Test, TDT 389.

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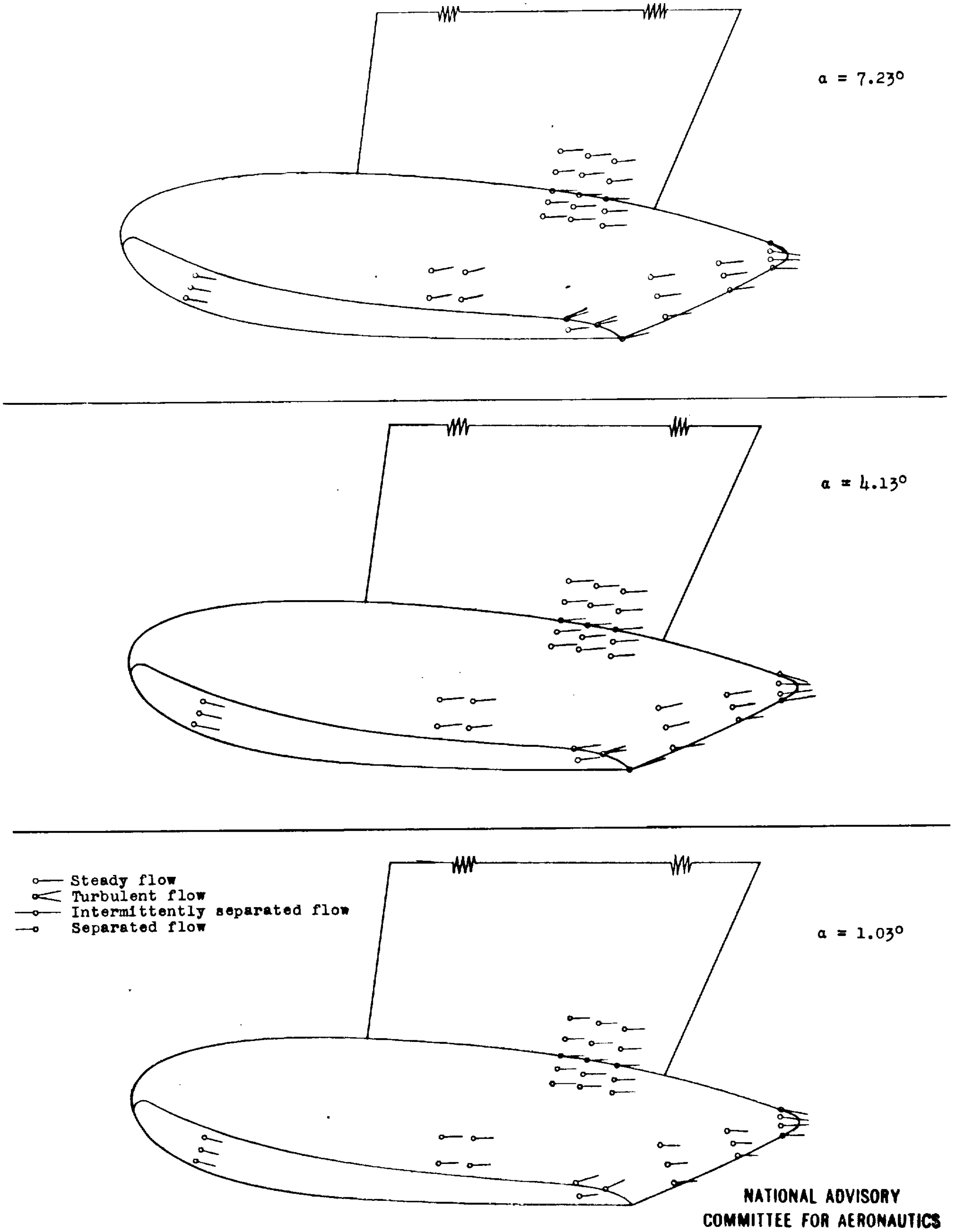

Figure 11.- Tuft observations of the 1/10-scale float-strut model for the Hughes-Kaiser Cargo Airplane; no afterbody step; float incidence 0° to wing chord; R, 7.0 × 10⁶. Test, TDT 386.